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Under this grant the researchers have investigated: (1) Laser instabilities, (2) Singular bifurcation to relaxation oscillations, (3) Slow passage through bifurcation points, (4) Propagation failure in discrete reaction-diffusion equations, (5) Large coherent fluid structures in boundary layers, (6) Primary and secondary flutter in flexible channel flows, (7) Energy leakage and reflection in slowly varying wave-guides, (8) Pulse dynamics in nonlinear optical fibers and switches and (9) Numerical modeling of optical pulse propagation.

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Final Technical Report for AFOSR Grant #90-0139, "The Stability and Dynamics of Elastic Structures and Fluid Flows"

E. L. Reiss, T. Erneux and W. L. Kath, *co-investigators*

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30 June 1993

1. Research Accomplishments

1.1 Laser instabilities

We have significantly expanded our study of laser instabilities.

With Paul Mandel, we have examined the slow passage through the Ar laser steady bifurcation point. We took into account the fact that all experiments have considered initial conditions close to the bifurcation point. We showed that the transition is described by a nonlinear evolution equation (Opt. Comm. **85**, 43-46, 1991). With M. Georgiou, we have analyzed limit-cycle laser oscillations by the method of matched asymptotic expansions. We showed that the slow and nearly zero intensity regime can be described as a slow passage problem. Consequently, the slow regime of the laser oscillations is highly sensitive to small amplitude noise. We then studied analytically and numerically the effect of noise (Phys. Rev. **A45**, 6636-6642, 1992).

With I. Schwartz, we investigated the bifurcation diagram of the periodically modulated laser in the limit of large amplitude oscillations. We applied the method of matched asymptotic expansions and derived a Poincaré map for the successive oscillations. We then showed that period doubling bifurcation is possible and compared our predictions with the results of a new numerical study of the laser problem ("Subharmonic hysteresis and period doubling bifurcations for a periodically driven laser", submitted to SIAM J. on Appl. Mathematics, 1992).

With R.-D. Li, we investigated the bifurcation to periodic standing and traveling wave solutions in arrays of coupled semiconductor lasers. We concentrated on the linear stability of a basic solution and showed that the first instability corresponds to a preferential spatio-temporal mode of oscillations (Phys. Rev. **A46**, 4252-4260, 1992). We also investigated the continuous limit and found that the bifurcation to the new states are different if the number of coupled lasers is even or odd (Bifurcation to standing and traveling waves in large arrays of coupled lasers, submitted to Phys. Rev. A, 1993). Furthermore, we analyzed the linear stability of a basic solution for series and parallel coupling. We demonstrated the stabilizing effect of parallel coupling (Opt. Comm. **99**, 196-200, 1993).

1.2 Singular bifurcation to relaxation oscillations

With S. Baer, we continued our study of the singular Hopf bifurcation to relaxation oscillations (SIAM J. Appl. Math. **46**, 721-739, 1986). In our previous analysis, we investigated a system of two first order nonlinear equations and showed how the bifurcation problem can be reduced to a weakly perturbed conservative system of two first order equations. We developed a method, based on analyzing nearly conservative quantities, to find the bifurcation diagram of the periodic solutions emerging from singular Hopf bifurcation points. Specifically, we analyze the bifurcation diagram of the Fitzhugh-Nagumo equations when the Hopf bifurcation is subcritical but nearly vertical. The extension from the earlier bifurcation analysis is achieved by performing a perturbation analysis from the first integral of the leading order nonlinear oscillator. It is observed that local to the change of criticality at a parameter q, the first integral exists up to an additional order in the perturbed equation. This condition allowed the resolution of features determined by higher order terms (SIAM J. on Appl. Mathematics **52**, 1651-1664, 1992).

With K. Deller and A. Bayliss, we investigated the Brusselator reaction-diffusion equations with periodic boundary conditions. We considered the range of values of the parameters used by Kuramoto in his study of chaotic concentration waves. We determined numerically the bifurcation diagram of the long-time traveling and standing wave solutions using a highly accurate Fourier pseudo-spectral method. For moderate values of the bifurcation parameter, we have found a sequence of instabilities leading either to periodic and quasiperiodic standing waves or, to chaotic regimes. However, for large values of the control parameter, we have found only uniform time-periodic solutions or time-periodic traveling wave solutions. Our numerical study has motivated a new asymptotic analysis of the Brusselator equations for large values of the control parameter and small diffusion coefficients. We found that relaxation oscillations have a stabilizing effect (Eur. J. on Applied Mathematics **2**, 341-358, 1991).

1.3 Slow passage through bifurcation points

We have explored analytically and numerically several slow passage through bifurcation or limit points. With E. Reiss, L. Holden and M. Georgiou, we reviewed all asymptotic results which have been obtained both for steady and Hopf bifurcations (In "Dynamic Bifurcations", Lect. Notes in Mathematics **1493**, 14-28, 1991). Of particular interest is the fact that nonlinear problems, which are not formulated as bifurcation problems, may require the study of a slow passage through a bifurcation point. This is the case of the so-called bursting oscillations. With L. Holden, we investigated a model of two allosteric enzymes coupled in series. From a numerical study of the kinetic equations, we found that the bursting solution strongly depends on a slow passage through a Hopf bifurcation. The transition is from a slowly varying branch of limit-cycle oscillations to a slowly varying branch of steady state solutions. We then showed that the delay of the transition can be explained by solving a non-autonomous amplitude equation (J. Math. Biol. **31**, 351-365 (1993); "Slow passage through a Hopf bifurcation: from oscillatory to steady state solutions". SIAM J. on Appl. Mathematics, in press, 1993).

1.4 Propagation failure in discrete reaction-diffusion equations

With G. Nicolis, we considered a discrete bistable reaction-diffusion system modeled by N coupled Nagumo equations. We developed an asymptotic method to describe the phenomenon of propagation failure. The Nagumo model depends on two parameters: the coupling constant d and the bistability parameter a. We investigated the limit $a \to 0$ and $d(a) \to 0$ and constructed traveling front solutions. We obtained the critical coupling constant $d = d^*(a)$ above which propagation is possible and determined the propagation speed $c = c(d)$ if $d > d^*$ ("Propagating waves in discrete bistable reaction-diffusion systems", Physica D, in press, 1993). With V. Booth, we applied this analysis to the case of nonuniform coupling in the population (Physica A **188**, 206-209, 1992). With J.-P. Laplante, we studied experimentally moving fronts propagating in a system of 16 bistable coupled chemical reactors. We determined the speed of the front and showed that it fails to propagate if the exchange rate is below a non zero value (Physica A **188**, 89-98 (1992); J. Phys. Chem. **96**, 4931-34, 1992).

1.5 Large coherent fluid structures in boundary layers

We have considered the propagation of acoustic waves from a high-frequency line source in a shear layer flowing over an infinite elastic plate. The fluid was taken to be inviscid and compressible. Lagrange-Kirchhoff linear plate theory, including structural damping, was used to describe the small amplitude motions of the plate. The resulting problem was solved approximately by first obtaining the integral representation of the solution using Fourier transforms, and then obtaining asymptotic expansions of this expression for high-frequency sources, as we have done previously for shear flow over a rigid wall. An infinite sequence of caustics (localized noisy regions) are created, downstream of the source and adjacent to the elastic surface, by the refraction of rays from the source and their subsequent reflections from the plate. The acoustic fields on and off the caustics, and in the near and the far field, were obtained from the asymptotic solution. Because of the structural damping, large attenuation of the caustic sound field is obtained for special values of the plate and fluid parameters (Abrahams, Kriegsmann and Reiss, J. Acoust. Soc. of Amer. **92**, 1992).

1.6 Primary and secondary flutter in flexible channel flows

A mathematical model for the nonlinear stability of two-dimensional leakage channels was formulated and analyzed. It consists of an infinite channel with flexible elastic walls containing a flowing viscous, incompressible fluid. Two infinite elastic plates are inserted into the channel, parallel to the walls, to form parallel channels. The walls and the parallel plates were modeled by the Von Kármán non-linear plate theory. To simplify the analysis, the fluid viscosity was modeled by Darcy's law rather than the Navier-Stokes law. Plug flow, where the fluid velocity is constant in each channel and the deflection of each wall is constant, is a solution of the problem for all values of the flow speed. The stability of the plug flow state was tested by linearized stability theory. Stability is lost either by divergence or by flutter.

The critical value of the flow speed depends on the system parameters and the mode of oscillation, either symmetric or antisymmetric. The non-linear problem was solved by the Poincaré-Linstedt method near the critical flow speed for flutter. One or more branches of flutter solutions bifurcate from this critical speed depending on the multiplicity of the critical speed. It was shown, depending on the ranges of the system parameters, that the bifurcation is either supercritical or subcritical and that the supercritical (subcritical) solutions are stable (unstable). Finally, it was shown that the secondary bifurcation of flutter states may occur depending on the values of the system parameter. In addition, "mode jumping" between flutter states may occur via the secondary bifurcation states, which are then quasi-periodic solutions of the non-linear problem (Prince, Grotberg and Reiss, J. Sound and Vibration **161**, 1993).

1.7 Energy leakage and reflection in slowly varying waveguides

We have presented a new technique, which we call the method of slowly varying dispersion relations, for approximately determining the modes near cut-off in two-layer slowly varying waveguides. The depth of the upper layer is finite while the lower layer is semi-infinite. We have applied the method to the penetration problem, where the density and sound speed ratios are O(1), which was analyzed previously by different methods, and for which it was shown that all of the energy propagating in the upper layer was lost into the underlying layer. We show that using slowly varying dispersion relations more quickly leads to these results. We have also applied the method to the case where the lower layer is hard and fast compared to the upper layer. In this case energy is both lost into the lower layer and reflected back into the waveguide. A new canonical integral derived with the method gives quantitative results for the pattern of the radiation transmitted into the lower layer and the amount of reflected energy (Kath, Minzoni, Kriegsmann and Reiss, J. Acous. Soc. of Amer., **93**, 1993).

1.8 Pulse dynamics in nonlinear optical fibers and switches

The goal of this part of the project has been the development of approximate methods appropriate for modeling the dynamics and propagation of pulses in nonlinear optical fibers, and the use of these methods in the study of a number of specific physical applications. The applications are typically described by infinite dimensional Hamiltonian field equations, such as coupled nonlinear Schrödinger (NLS) equations, and are perturbations of systems which are completely integrable by the Inverse Scattering Transform. The methods developed involve elements from both perturbation and variational methods; the intent is to accurately describe the pulse dynamics using a relatively small number of degrees of freedom.

The applications which were considered are problems involving the interaction of pulses in nonlinear optical fibers, specifically the propagation of pulses with two interacting polarizations. The potential application of devices incorporating such effects (e.g., soliton logic gates) to optical communication systems is currently being investigated by various researchers. In the problems studied a hybrid perturbative-variational method was used to investigate the dynamics and propagation of pulses in birefringent (two-polarization) nonlinear optical fibers. Good agreement was found when the low-dimensional approximations obtained with the method were directly compared with numerical solutions of the full partial differential equations (Ueda and Kath, Phys. Rev. A. **42**, 1990; Muraki and Kath, Physica D **48**, 1991; Ueda and Kath, Physica D, **55**, 1992).

Additional interest in these hybrid variational methods has been generated due to the recent report that they provide an efficient method for modeling the dynamics of soliton dragging logic gates (Wang, et al., "Numerical modeling of soliton dragging logic gates", J. Opt. Soc. Amer. B, to appear, 1993); in particular, the variational method described above proved to be the most accurate among the several approximate methods tested. Soliton dragging logic gates are all-optical, cascadable, ultrafast logic gates which have been demonstrated experimentally by Islam (*Ultrafast Fiber Switching Devices and Systems*, Cambridge Studies in Modern Optics, No. 12, Cambridge University Press, 1992). They have the potential to operate at bit rates as high as 200 Gb/s, and all-optical ring networks based upon these devices have been designed. Such high-level systems obviously require a large number of logic gates, and it is computationally excessive to be required to solve a large number of coupled NLS equations in order to predict the behavior of such systems. It is for this reason that accurate, low-dimensional approximations such as the variational models described above are desirable; being able to determine system behavior from the solution of a set of coupled ordinary differential equations is much more efficient than having to solve a set of coupled partial differential equations.

1.9 Numerical modeling of optical pulse propagation

A mathematical model and one-dimensional numerical implementation of Maxwell's equations for the propagation of soliton-like pulses in nonlinear dispersive optical media was developed. The model includes linear dispersion, expressed in the time-domain, and a Kerr nonlinearity. Also incorporated in the model is a coordinate system moving with the group velocity of the pulse, which allows significant reduction of the size of the computational grid. A key feature of the work was an asymptotic analysis of the partial differential equations (PDEs) used to reduce them to the Nonlinear Schrödinger (NLS) equation. This allowed the direct generation of initial conditions for the PDEs corresponding to solutions of the NLS equation (such as soliton solutions), provided a method for direct comparison of the numerical results and solutions of the NLS equation, and allowed the evaluation of third harmonics induced by the nonlinearity in the propagating pulses. Several specific examples were examined to show the good agreement between the theory and the numerics.

These direct comparisons also showed, however, that the NLS equation provides an excellent approximation of one-dimensional nonlinear optical pulse propagation even in situations where one might not expect it to be. The NLS equation is an asymptotic approximation which is valid in the limit of large pulse widths (in comparison with a typical wavelength); the numerical results show that (at least for the case of a single resonance linear dispersion and instantaneous nonlinearity) the NLS equation provides a very good approximation even when a pulse contains as few as 10 or so optical cycles. This suggests that in one dimension extended NLS equations (Agrawal, *Nonlinear Fiber Optics*, Academic Press, 1992), as long as they appropriately model the underlying physics, should give very good results even at quite short pulse widths. In addition, although this conclusion is based only on one-dimensional calculations, we also expect it to be true in two and three dimensions for propagation in waveguiding structures, since such structures essentially reduce the problem to propagation in one dimension.

1.10 Phase-sensitive optical amplification

In the latter part of the award period work began on the modeling of novel optical amplifiers. The use of lumped (i.e., periodically-spaced) erbium-doped fiber amplifiers has been demonstrated as a method for cancelling loss in long-distance optical communication systems. These erbium-doped fiber segments amplify signals via stimulated emission; they are pumped with a diode laser to maintain a population inversion, in a manner similar to a laser. The population inversion generates spontaneous emission noise, however, which causes an effect known as Gordon-Haus jitter — the random walk of solitons caused by frequency shifts induced by the noise — and this jitter imposes an overall limit on the maximum allowable bit rate.

As a possible alternative to erbium-doped amplifiers, the use of lumped phase-sensitive amplifiers (e.g., phase-matched, degenerate parametric amplifiers) has been suggested. Phase-sensitive amplifiers should lead to a higher bit-rate limit because they produce no spontaneous emission noise. We have recently completed the first theoretical study of pulse evolution in a nonlinear optical fiber where linear loss is balanced by a chain of periodically-spaced, phase-sensitive amplifiers (Kutz, Kath, Li and Kumar, Integrated Photonics Research Technical Digest, Optical Society of America, **10** 1993). The results show that pulse propagation is stabilized by the use of these amplifiers. We have also been able to show that some of these stabilizing effects are present even for linear pulses.

2. Publications in reviewed journals

Papers Published, Accepted for Publication and Submitted
During 3/1/90 - 2/28/93

1. Hobbs, A. K. and Kath, W. L., Loss and Birefringence for Arbitrarily Bent Optical Fibers, IMA J. of Appl. Maths. **44** (1990), pp. 197–219.

2. Erneux, T. and Reiss, E. L., Delaying the Transition of Hopf Bifurcation by Slowly Varying the Bifurcation Parameter, in "Spatial Inhomogeneites and Transient Behavior in Chemical Kinetics," P. Gray, G. Nicolis, F. Baras and P. Borckmans, S.K. Scott, eds., Manchester U.P., Manchester, England (1990).

3. Kath, W. L., Jiao, J. and Marhic, M. E., Boundary Layer Analysis of Infrared Whispering Gallery Waveguides, SIAM J. Appl. Math. **50** (1990), pp. 537–546.

4. Ahluwalia, D. A., Kriegsmann, G. A. and Reiss, E. L., Direct and Inverse Scattering of Acoustic Waves by Low Speed, Free Shear Layers, J. Acoust. Soc. of Am. **88** (1990), pp. 1596–1602.

5. Cohen, D. S. and Erneux, T., Changing time history in moving Boundary Problems, SIAM J. Appl. Math. **50** (1990), pp. 483–489.

6. Braza, P. A. and Erneux, T., Constant Phase, Phase Drift, and Phase Entrainment in Lasers with an Injected Signal, Phys. Rev. **A41** (1990), pp. 6470–6479.

7. Li, Ruo-Ding, Mandel, P. and Erneux, T., Periodic and Quasiperiodic Regimes in Self-Coupled Lasers, Phys. Rev. **A41** (1990), pp. 5117–5126.

8. Ueda, T and Kath, W. L., Dynamics of Coupled Solitons in Nonlinear Optical Fibers, Phys. Rev. A. **42** (1990), pp. 563–571.

9. Muraki, D. J. and Kath, W. L., Hamiltonian Dynamics of Solitons in Optical Fibers, Physica D **48** (1991), pp. 53–64.

10. Bourland F. J., Haberman, R. and Kath, W. L., Averaging Methods for the Phase Shift of Arbitrarily Perturbed Strongly Nonlinear Oscillators, SIAM J. on Appl. Math. **51** (1991), pp. 1150–1167.

11. Villamizar, V., Kriegsmann, G. A. and Reiss, E. L., Acoustic Scattering From Baffled Membranes that are Backed by Elastic Cavities, Wave Motion **14** (1991), pp. 290–320.

12. Erneux, T. and Schwartz, I. B., A New Asymptotic Theory for the Periodically Forced Laser, OSA Proceedings on Nonlinear Dynamics in Optical Systems 7 (1991), pp. 384–388.

13. Laplante, J. P., Erneux, T. and Georgiou, M., Jump Transition Due to a Time-Dependent Bifurcation Parameter. An Experimental, Numerical and Analytical Study of the Bistable Iodate-Arsenous Acid Reaction, J. Chem. Phys. **94** (1991), pp. 371–378.

14. Erneux, T. and Mandel, P., Slow passage through the laser first threshold: influence of the initial conditions, Opt. Comm. **85** (1991), pp. 43–46.

15. Deller, K., Erneux, T. and Bayliss, A., Asymptotic and Numerical Study of Brusselator Chaos, Eur. J. on Applied Mathematics **2** (1991), pp. 341–358.

16. Li, Ruo-Ding, Mandel, P. and Erneux, T. Optical Parametric Generator and Oscillator with Nonlinear Losses, JOSA B **8** (1991), pp. 1835–1842.

17. Erneux, T., Reiss, E. L., Holden, L. and Georgiou, M., Slow Passage through a Bifurcation Point. Asymptotic Theory and Applications. In "Dynamic bifurcations", Lecture Notes in Mathematics **1493** (1991), pp. 14–28.

18. Ueda, T. and Kath, W. L., Dynamics of Pulses in Randomly Birefringent Nonlinear Optical Fibers, Physica D, **55** (1992), pp. 166–181.

19. Kath, W. L., Hobbs, A. K. and Kriegsmann, G. A., Bending losses in optical fibers, Proceedings of the NATO Workshop on *Asymptotics Beyond All Orders*, Plenum Press, New York, 1992, H. Segur et al., editors.

20. Georgiou, M. and Erneux, T., Pulsating Laser Oscillations Depend on Extremely Small Amplitude Noise, Phys. Rev. **A45** (1992), pp. 6636–6642.

21. Laplante, J. P. and Erneux, T., Propagation Failure in Arrays of Coupled Bistable Chemical Reactors, J. Phys. Chem. **96** (1992), pp. 4931–4934.

22. Baer, S. M. and Erneux, T., Singular Hopf Bifurcation to Relaxation Oscillations II, SIAM J. on Appl. Mathematics, **52**, 1651–1664 (1992).

23. Li, Ruo-Ding and Erneux, T., Preferential Instability in Arrays of Coupled Lasers, Phys. Rev. A **46**, 4252–4260 (1992).

24. Booth, V. and Erneux, T., Mechanisms for Propagation Failure in Discrete Reaction-Diffusion Systems, Physica A **188**, 206–209 (1992).

25. Laplante, J.P. and Erneux, T., Propagation Failure and multiple steady states in an Array of Diffusion Coupled Flow Reactors, Physica A **188**, 89-98 (1992).

26. Abrahams, I. D., Kriegsmann, G. A. and Reiss, E. L., On the Development and Control of Caustics in Shear Flows over Elastic Walls, J. Acous. Soc. of Amer. **92**, 428–434 (1992).

27. Erneux, T. and Cohen, D.S., Moving Boundary Problems in Controlled Release Pharmaceuticals, Proceedings of the conference "Free Boundary Problems: Theory and Applications" (Eds. J. Chadam and H. Rasmussen), Pitman Research Notes in Mathematics, **280**, 161–165 (1993).

28. Holden, L. and Erneux, T., Understanding Bursting Oscillations as Periodic Slow Passages through Bifurcation and Limit Points, J. Math. Biol. **31**, 351–365 (1993).

29. Li, R.-D. and Erneux, T., Stability Conditions for Coupled Lasers: Series Coupling vs. Parallel Coupling, Opt. Comm. **99**, 196–200 (1993).

30. Erneux, T. and Davis, S.H., Nonlinear Rupture of Free Films, Phys. Fluids A **5**, 1117-1122 (1993).

31. Mandel, P., Georgiou, M. and Erneux, T., Transverse effects in coherently driven nonlinear cavities, Phys. Rev. **A47**, 4277 (1993).

32. Prince, A. S., Grotberg, J. B., and Reiss, E. L., Primary and Secondary Flutter of Leakage Flow Channels, J. Sound and Vibration **161** 89-107 (1993).

33. Kath, W. L., Minzoni, A. A., Kriegsmann, G. A. and Reiss, E. L., Energy Leakage and reflection in Slowly Varying Waveguides, J. Acous. Soc. of Amer., **93** #1 (1993), pp. 182–187.

34. Hile, C. V. and Kath, W. L., A numerical and asymptotic solution of Maxwell's equations for nonlinear optical pulse propagation, in Integrated Photonics Research Technical Digest (Optical Society of America, Washington, D.C.), Vol. 10 (1993), pp. 308–311.

35. Kutz, J. N., Kath, Kath, W. L., Li, R.-D., and Kumar, P., Stable long-distance pulse propagation in nonlinear optical fibers using periodically-spaced parametric amplifiers, in Integrated Photonics Research Technical Digest (Optical Society of America, Washington, D.C.), Vol. 10 (1993), pp. 48–50.

36. Holden, L. and Erneux, T., Slow Passage Through a Hopf Bifurcation: from Oscillatory to Steady State Solutions, SIAM J. Appl. Math., in press (1993).

37. Nicolis, G. and Erneux, T., Propagating Waves in Discrete Bistable Reaction-Diffusion Systems, Physica D, in press (1993).

38. Schwartz, I.B. and Erneux, T., Subharmonic Hysteresis and Period Doubling Bifurcations for a Periodically Driven Laser, submitted to SIAM J. on Appl. Mathematics (1993).

39. Li, R.-D. and Erneux, T., Bifurcation to Standing and Traveling Waves in Large Arrays of Coupled Lasers, submitted to Phys. Rev. A (1993).

40. Erneux, T., Edstrom, R.D. and Goldbeter, A., Enzyme Sharing in Phosphorylation-Dephosphorylation cascades: the case where one Protein Kinase (or Phosphatase) acts on two Different Substrates, J. Theor. Biol. in press (1993).

41. Ueda, T. and Kath, W. L., Stochastic simulation of pulses in nonlinear optical fibers with random birefringence, submitted.

42. Hile, C. V. and Kath, W. L., A numerical and asymptotic solution of Maxwell's equations for nonlinear optical pulse propagation, submitted to J. Opt. Soc. Amer. B.

43. Abrahams, I. D., Kriegsmann, G. A. and Reiss, E. L., Sound Radiation and Caustic Formation from a Point Source in a Wall Shear Layer, submitted to AIAA J. (1992)

44. Abrahams, I. D., Kriegsmann, G. A. and Reiss, E. L., Downwind Noise Propagation from Wind Turbines, submitted.

45. Villamizar, V., Elastic Scattering from a Viscous Incompressible Fluid Sphere at Low Reynolds Number, submitted.

3. Books or book chapters published: (none)

4. Graduate Students supported

Thomas Carr (90-92)

Tetsuji Ueda (90-91)

Cheryl V. Hile (91-93)

Ann Niculae (92-93)

5. Postdoctoral associates and visitors supported

Ruo-Ding Li (Spring 1991; from Univ. of Brussels)

Nicolas Pettiaux (Spring 1991; from Univ. of Brussels)

Prof. Noel Smyth (Summer 1991; from Univ. of Edinburgh)

Ruo-Ding Li (91-92)

6. Invited presentations at conferences and universities (3/1/90 - 2/28/93)

6.1 T. Erneux

1. A series of nine lectures on "Laser Instabilities" given at the Free University of Brussels in Nov. 1990.

2. Propagation failure in a bistable system. Theoretical Biology Day, Mathematical Research Branch, July 1991.

3. Bursting oscillations in a biochemical model: the slow passage through a Hopf bifurcation, Society for Mathematical Biology Meeting, Santa Fe, New Mexico, August 1991.

4. Slow passage through bifurcation points. Department of Mathematics, Southern Methodist University, Dallas, Texas, September 1991.

5. XXth Solvay Conference on Physics entitled "Quantum Optics", Brussels, Belgium, November 1991.

6. Mechanisms for propagation failure in discrete reaction-diffusion systems. NATO Advanced Research Workshop entitled "Nonequilibrium Chemical Dynamics: from Experiment to Microscopic Simulations". Brussels, Belgium, December 1991.

7. Propagation failure in coupled excitable cells: asymptotic theory and experiments, Arizona State University, Tempe, Arizona, April 1992.

8. Quasi-vertical Hopf bifurcation for the multimode class B laser. Nonlinear Dynamics in Optical Systems Topical Meeting. Alpbach, Austria, June 1992.

9. From harmonic to pulsating periodic solutions in intracavity second harmonic generation. Nonlinear Dynamics in Optical Systems Topical Meeting. Alpbach, Austria, June 1992.

10. Bifurcation to standing and traveling waves in large lasers arrays. Nonlinear Dynamics in Optical Systems Topical Meeting. Alpbach, Austria, June 1992.

11. Class B laser oscillations. Society for Industrial and Applied Mathematics conference on Applications of Dynamical Systems. Snowbird, Utah, October 1992.

12. Bursting oscillations and slow passage through bifurcation points. Society for Industrial and Applied Mathematics conference on Applications of Dynamical Systems. Snowbird, Utah, October 1992.

13. Coupled Lasers, Stability, Bifurcations and Large Arrays. Phillips Lab., Albuquerque, NM, May 1993.

6.2 W. L. Kath

1. "Dynamics of pulses in birefringent optical fibers", Society for Industrial and Applied Mathematics Conference on Dynamical Systems, Orlando, FL, May 1990.

2. "Energy leakage and reflection in underwater upslope acoustic wave propagation", Society for Industrial and Applied Mathematics Annual Meeting, Chicago, IL, July 1990 (also, chair of session).

3. "Hamiltonian dynamics optical fiber solitons", Minisymposium on *Dynamics of Nonlinear Waves*, Society for Industrial and Applied Mathematics Annual Meeting, Chicago, IL, July 1990 (also, organizer of minisymposium).

4. Invited speaker, "Dynamics of pulses in birefringent nonlinear optical fibers", Workshop on *Nearly Integrable Wave Phenomena in Nonlinear Optics*, Department of Mathematics, Ohio State, December 1990.

5. Invited speaker, "Bending losses in optical fibers", *Asymptotics Beyond All Orders*, NATO Advanced Research Workshop, University of California, San Diego, January 1991.

6. Invited presenter, "Polarization decorrelation of pulses in randomly birefringent nonlinear optical fibers", Workshop on *Computational Optics: its links with Computational Fluid Dynamics*, Department of Mathematics, University of Arizona, March 1992.

7. Organizer, Minisymposium on *Asymptotic & Perturbation Methods in Nonlinear Wave Propogation*, Society for Industrial and Applied Mathematics 40th Anniversary Meeting, Los Angeles, July 1992.

8. Invited speaker, "Pulse Dynamics in Nonlinear Optical Fibers", Minisymposium on *Guided Wave Propogation*, Society for Industrial and Applied Mathematics 40th Anniversary Meeting, Los Angeles, July 1992.

9. "Dynamics of Pulses in Nonlinear Optical Fibres", Department of Mathematics, University of Edinburgh, August 1992.

10. Organizer, Minisymposium on *Nonlinear Optics and Hamiltonian Systems*, Society for Industrial and Applied Mathematics conference on Applications of Dynamical Systems, Snowbird, Utah, October 1992.

11. "Mathematical aspects of soliton propagation in nonlinear optical fibers", Department of Mathematics, University of Michigan, January 1993.